Enclosure 2
Technical Report
The Feasibility of Modifying the Calculation of Reportable Volatile Organic Compound Content for Architectural Coatings

I. Background

Since the 1970s, U.S. EPA rules and guidance documents have required that the VOC content of coating products be determined on a "less water and exempt compounds basis." Although the U.S. EPA has adopted standards such as weight per weight of solids, weight per volume solids, and weight percent for other types of regulations, this approach continues to be used in architectural coatings. This approach (referred to hereafter as "VOC regulatory") is contained in district architectural coatings rules and other coatings rules in California. This approach is also used in the ARB's June 2000 Suggested Control Measure (SCM) for architectural coatings. However, in response to industry comments received during the June 22, 2000, Board meeting, the Board directed the ARB staff to reexamine the calculation method and provide an update to the Board by June 2001 on the feasibility of modifying the calculation. To date, ARB staff has held two conference calls to discuss this topic with industry, on November 16, 2000, and April 30, 2001.

II. The VOC Regulatory Approach

VOC regulatory (also called VOC coating) is calculated according to the following equation:

$$\text{VOC Content} = \frac{W_{vm}-W_w-W_{ec}}{V_m-V_w-V_{ec}} = \frac{W_{voc}}{V_{voc}+V_s}$$

Where:
VOC Content = grams (or pounds) of VOC per liter (or gallon) of coating, less water and exempt compounds
W_{vm} = weight of all volatiles in grams (or pounds)
W_w = weight of water in grams (or pounds)
W_{ec} = weight of exempt compounds in grams (or pounds)
W_{voc} = weight of VOC in grams (or pounds)
V_m = volume of coating in liters (or gallons)
V_w = volume of water in liters (or gallons)
V_{ec} = volume of exempt compounds in liters (or gallons)
V_{voc} = volume of VOC in liters (or gallons)
V_s = volume of solids in liters (or gallons)

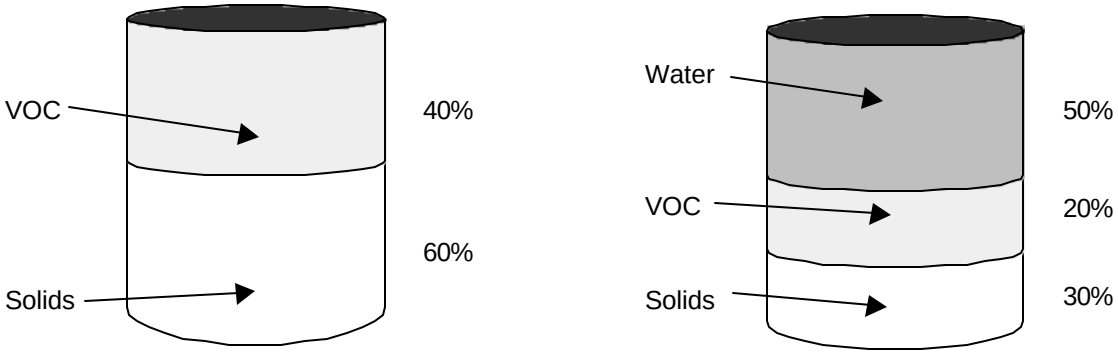
The term W_{vm} in the numerator of the equation is the weight of all volatile materials, which are the materials that would tend to evaporate when the coating is applied. The volatile materials include VOC solvents, water, and exempt solvents. Therefore, when water and exempt compounds are subtracted from $W_{vm,}$ the numerator of the equation simply represents the weight of VOC solvents. The term V_m in the denominator is the volume of the entire coating. Therefore, when the volume of water and exempt compounds are removed, the denominator in the equation represents the combined volume of the VOC solvents and paint solids (resins, pigments, fillers). Thus, for a solvent-based product without exempt compounds, the VOC regulatory calculation simply represents the weight of VOC solvents, divided by the volume of the entire product. However, in the case of a water-based product, or solvent-based product containing exempt compounds, the water or exempt compounds are removed from both the numerator and denominator, effectively removing them from consideration. The equation then represents only the remaining contents in the product (volume VOC solvents and solids) again as the ratio of the weight of VOC solvents to the combined volume of the VOC solvents plus coating solids.

An alternative VOC equation is VOC actual, also known as VOC material. VOC actual is the ratio of the weight of the VOC to the volume of the entire coating, including water and any exempt compounds (see Section V below). Using the terms defined above, VOC actual is calculated according to the following equation:

$$VOC_{content} = \frac{W_{vm} - W_w - W_{ec}}{V_m} = \frac{W_{voc}}{V_m}$$

Figure 1 gives a visual representation of the volume of VOC, solids, and water for a typical solvent-based and water-based coating. Making an assumption about the density of the VOC, Figure 1 also identifies the VOC regulatory and VOC actual for the two coatings.

Figure 1



Solvent-borne
VOC Regulatory = 352 g/L
VOC Actual = 352 g/L

Water-borne
VOC Regulatory =352 g/L
VOC Actual = 176 g/L

III. Rationale for VOC Regulatory Calculation

The rationale for the VOC regulatory calculation is that, for the purposes of determining VOC emissions, the chief concern is the mass of VOC emitted per volume of coating solids (Brezinski, p. 8). The weight of VOC solvents in the product will dictate the amount of VOC emissions assuming that all VOC solvents are ultimately emitted. The volume of coating solids in the product will theoretically dictate the coverage achieved by the product. Using this reasoning, the best measure of the VOC content would be the ratio of the weight of the VOC solvents to the volume of coating solids (weight VOC/volume solids). However, due to difficulties in measuring the volume of solids in the laboratory, the VOC regulatory calculation is used (Brezinski, p.7 ; U.S. EPA letter to ARB dated 3/15/77). The VOC regulatory calculation differs in that the denominator includes the volume of both solids and VOCs. However, according to the U.S. EPA, the VOC regulatory calculation is a reasonable surrogate for the weight VOC/volume solids ratio, because it ranks products similarly (U.S. EPA letter to ARB dated 4/13/82). Nevertheless, a key assumption for both VOC regulatory and the weight VOC/volume solids ratio is that the volume of solids dictates, or at least is reasonably related to, the amount of surface area the coating will cover. This property of a coating is called coverage. As discussed in the "Issues" section below, some members of industry have questioned the validity of this assumption. Figures 2, 3, and 4 show graphically how VOC actual, VOC regulatory, and weight VOC / volume solids change as the volume solids, volume VOC and volume water are kept constant.

Figure 2

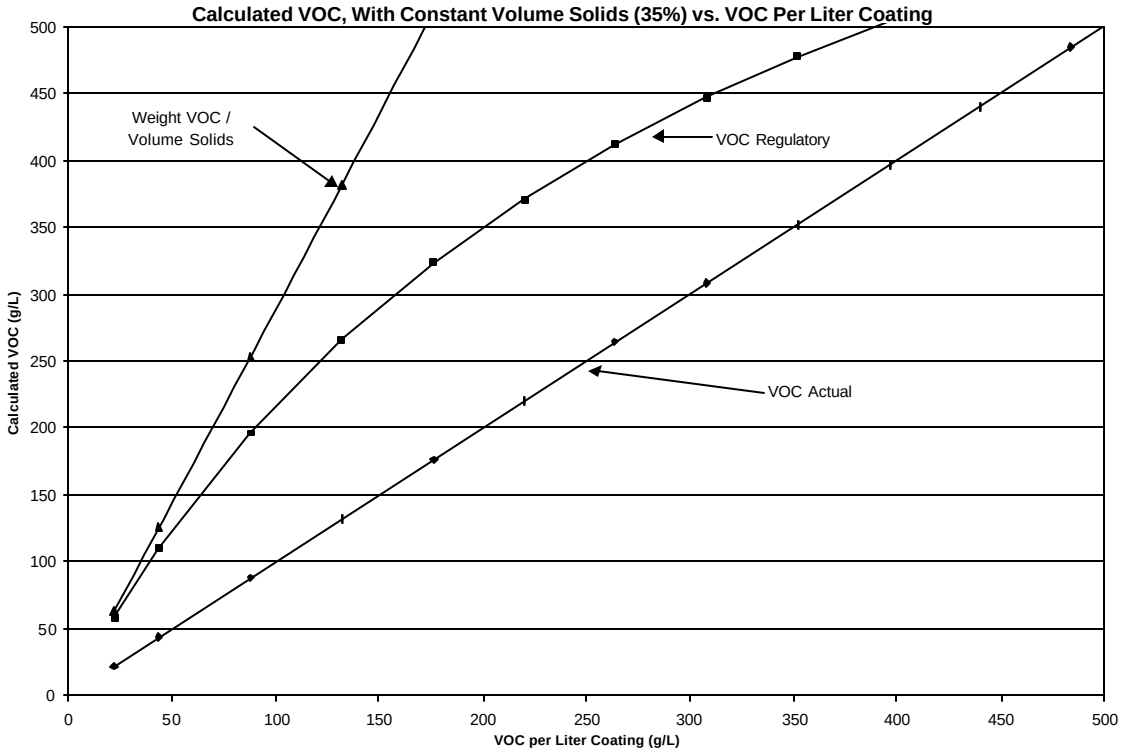


Figure 3

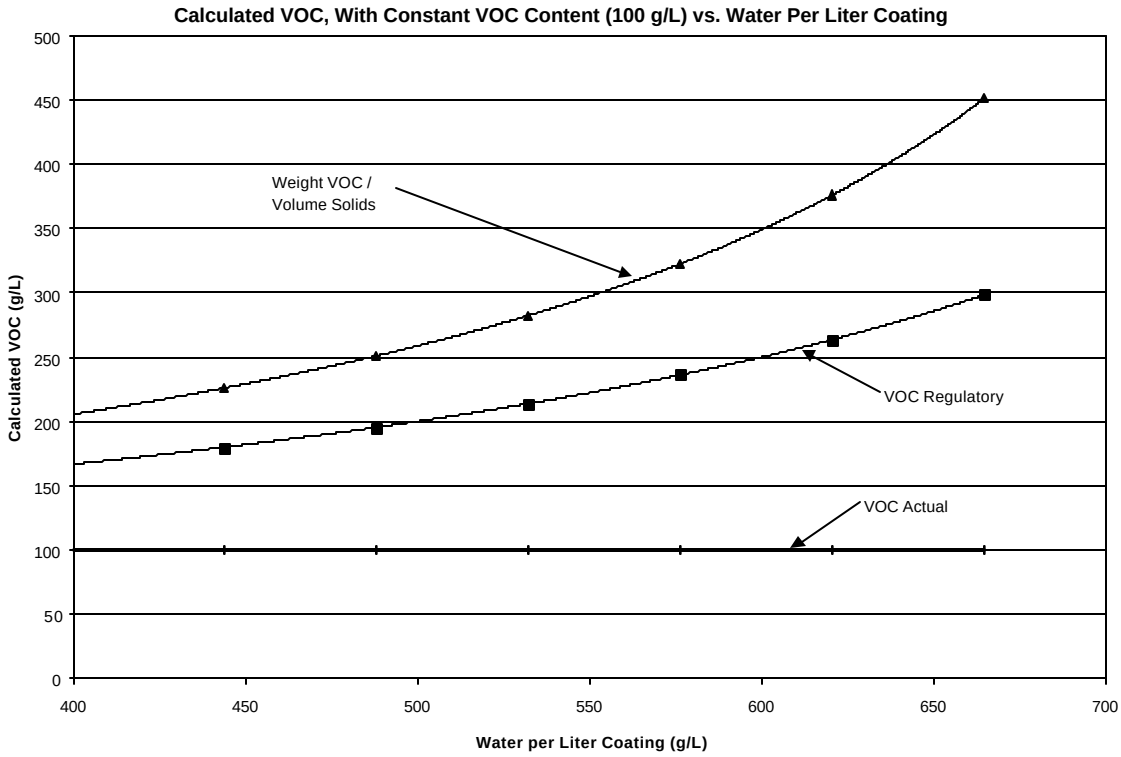
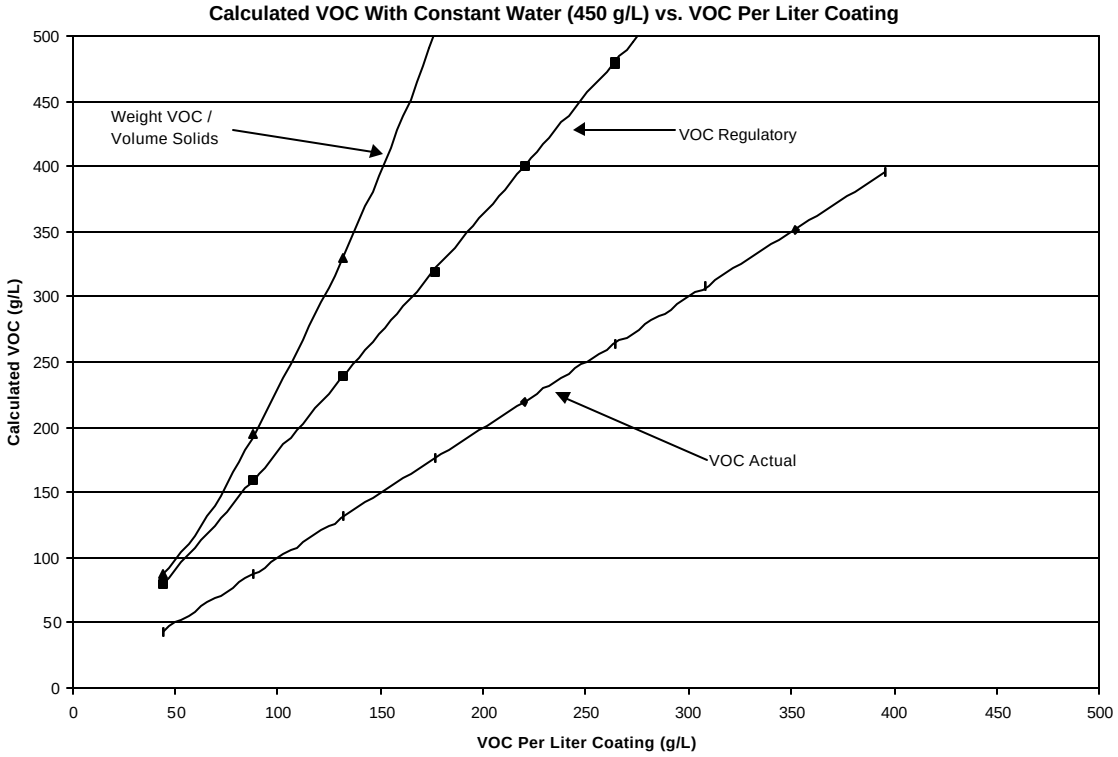


Figure 4



IV. Issues with VOC regulatory

1) Issue: Water-based products (or products with exempt solvents) are penalized because the VOC regulatory is higher than the VOC actual.

Response: Water-based products (or products with exempt solvents) will have a higher VOC regulatory than VOC actual, while solvent-based products without exempt compounds will have the same value for VOC regulatory and VOC actual. This is because the VOC regulatory ratio subtracts the water and exempt compounds out of both the numerator and denominator, which increases the VOC value of water-based products, but has no effect on solvent-based products. Whether this unfairly penalizes water-based products is debatable. If one assumes that the volume solids content of paint is directly related to coverage, then the VOC regulatory value is appropriate, because it measures the VOC emissions of both water-based and solvent-based products on an equal (solids related) basis. If volume solids levels are not related to coverage, and a can of lower solids water-based paint has similar coverage to a can of higher solids solvent-based paint (with an equivalent VOC regulatory, but a higher VOC actual), then the VOC regulatory calculation may penalize water-based products. ARB staff review of product data sheets of coatings from the major coating categories in the 2000 Suggested Control Measure with lower future VOC limits indicates that there is not a consistent relationship between volume solids levels and coverage. These categories include flats, nonflats, lacquers, industrial maintenance coatings, quick dry enamels, primers, sealers and undercoaters, quick dry primers, sealers and undercoaters, waterproofing sealers, and stains. However, a research project where typical water-based and solvent-based products of varying volume solids levels are applied in typical situations (or per available ASTM tests) is needed to further investigate the correlation between volume solids and coverage (See Section VIII).

It should also be noted that if the VOC limits were revised to VOC actual, the limits would be much lower to achieve the same emission reductions as the current VOC regulatory limits. ARB staff prepared a table with the VOC actual limits that would correspond to the VOC regulatory limits currently in the SCM (See Table 1). As an example, the future VOC regulatory limit of 100 grams per liter (less water) for flat coatings would correspond to a VOC actual limit of 40 grams per liter. The values in Table 1 assume that the percent volume solids per coating stays constant, and the volume of each coating will not increase.

Table 1

Estimated VOC Actual, % VOC by Weight, and Weight VOC per Volume Solids Limits

Category	VOC Regulatory Limit (g/L)	VOC Actual Limit (g/L)	% VOC By Weight	Weight VOC / Volume Solids (g/L)
Flat Coatings	100	40	3%	114
Non-Flat Coatings - Medium/Low Gloss	150	65	6%	176
Industrial Maintenance Coatings	250	195	16%	323
Lacquers	550	320	34%	1452
Primer, Sealer, and Undercoaters	200	145	12%	386
Quick-Dry Enamel Coatings	250	175	16%	349
Quick-Dry Primer, Sealer, and Undercoaters	200	125	10%	287
Stains	250	185	18%	508
Traffic Marking Coatings	150	95	6%	164
Waterproofing Sealers	250	185	19%	497

Based on 1998 ARB Architectural Coatings Survey.

2) Issue: We should switch from VOC regulatory to VOC actual, as we now do for low solids coatings (with less than one pound solids per gallon), when the ratio of VOC regulatory to VOC actual reaches 4 or 5 to 1.

Response: Currently, low solids coatings (less than one pound solids per gallon) are regulated according to their VOC actual because coverage is not related to volume solids with these products. For example, many low solids stains and waterproofing sealers are designed to leave a very thin film, or to penetrate the substrate while leaving a minimal film. Higher solids levels would defeat the purpose of these products and would not lead to higher coverage. For these products, increasing the amount of water or exempt compounds is the only way to reduce VOC emissions. In addition, since the VOC regulatory calculation subtracts out the water and exempt compounds, and there are very little solids in these products, the VOC regulatory value would approach the VOC regulatory value of pure solvent.

The commenter is proposing another method of qualifying certain low solids products to be subject to the VOC actual calculation. ARB staff analyzed the major product categories to determine which had products meeting a 3, 4, or 5 to 1 ratio due to lower solids levels (that is, having significantly lower solids than the other products in the same category). Based on the analysis, three product categories were identified that had at least a minimal level of products meeting these criteria (waterproofing sealers, stains, and primer/sealer/undercoaters – PSUs). Of the three categories, waterproofing sealers had the highest market share meeting the 4 or 5 to 1 ratio, with about 36% meeting both the 4 to 1 and 5 to 1 ratio. In addition, about 30% of the market within these ratio ranges do

not meet the 250 g/l VOC regulatory limit in the SCM, while all would comply with an alternative equivalent 120 g/l VOC actual limit. Therefore, a large part of the market in this category would benefit by allowing products meeting the 4 or 5 to 1 ratio to be subject to the VOC actual calculation (see Tables 2 and 3). The effect for stains and PSUs would be minimal since less than 7% of the market in each of these categories falls within the ratios, and less than 2% of the market falls within the ratios and does not meet the VOC regulatory limit in the SCM. This was especially true of the PSU category, where less than 0.1% of the market met these conditions. Although only one category would benefit from the proposed change, it may be worthwhile to further investigate whether products meeting the 4 or 5 to 1 ratio would be more appropriately subject to a VOC actual limit. As with other coatings, a key issue is whether the coverage obtained by these products is related to volume solids levels.

As a simpler alternative to the 4 or 5 to 1 ratio approach, staff also analyzed the impact of changing the low-solids definition from 1 pound of solids to 1.5 or 2 pounds of solids (see Tables 4 and 5). Although the data are incomplete, the results show that such a change would benefit the waterproofing sealers and stains categories, while not creating a loophole for other categories.

3) Issue: Water-based products emit less VOC than solvent-based products with the same VOC regulatory value.

Response: It is true that a water-based product with the same VOC regulatory value as a solvent-based product will have less VOC solvent in the can. However, assuming the VOC densities are similar, it will also generally have less volume solids, because the ratio of weight of VOC to the volume of VOC plus solids will be the same with each. Whether the water-based products emit less VOC depends on whether volume solids levels are related to coverage. Theoretically, if the same film thickness of both the solvent-based and water-based coating results from using these products, and assuming there are no voids within the film, then the VOC emissions per coverage amount from each will be the same. However, if the water-based coating can achieve the same coverage with a thinner film thickness, or with the same film thickness but with voids inside the film, then it will result in less emissions.

However, a review of architectural coatings survey data revealed real-world examples of water-based coatings that have less VOC than would be expected based on the proportion of their volume solids content to that of a solvent-based coating with the same VOC regulatory. In addition, as stated above, ARB staff review of product data sheets indicates that there

Table 2

VOC Regulatory / VOC Actual Ratio Impact - Stains

VOCR/VOCA Ratio Range	Sales Weighted Average % By Volume Solids	Sales Weighted Average VOC Regulatory (g/L)	Number of Products	Marketshare	Number of Products That Do Not Meet the 250 g/L Limit	Marketshare That Does Not Meet the 250 g/L Limit	Number of Products that Do Not Meet the 250 g/L Limit, but Meet the 120 g/L (Actual) Limit for Low Solids Coatings	Emission Reduction Lost If These are Now Low-Solids Coatings (excluding South Coast AQMD) (tons/day)
All	36.4%	268	1324	100.0%	986	47.0%	76	0.010
3:1 and up	17.5%	204	198	13.3%	68	5.5%	68	0.010
4:1 and up	12.9%	188	105	6.9%	35	1.5%	35	0.003
5:1 and up	10.3%	163	54	4.3%	26	0.3%	26	0.001

Table 3

VOC Regulatory / VOC Actual Ratio Impact - Waterproofing Sealers

VOCR/VOCA Ratio Range	Sales Weighted Average % By Volume Solids	Sales Weighted Average VOC Regulatory (g/L)	Number of Products	Marketshare	Number of Products That Do Not Meet the 250 g/L Limit	Marketshare That Does Not Meet the 250 g/L Limit	Number of Products that Do Not Meet the 250 g/L Limit, but Meet the 120 g/L (Actual) Limit for Low Solids Coatings	Emission Reduction Lost If These are Now Low-Solids Coatings (excluding South Coast AQMD) (tons/day)
All	37.2%	335	175	100.0%	80	87.2%	26	0.050
3:1 and up	14.2%	336	43	36.9%	24	30.4%	24	0.050
4:1 and up	12.0%	337	36	36.0%	19	29.8%	19	0.049
5:1 and up	11.3%	337	31	35.7%	16	29.6%	16	0.049

Table 4

Low Solids Weight Limit Evaluation - Stains
(74.5% of Data by Volume - See Note)

Solids Weight Limit (lbs/gallon)	Sales Weighted Average % By Volume Solids	Sales Weighted Average VOC Regulatory (g/L)	Number of Products	Marketshare of Selected Data	Number of Products That Do Not Meet the 250 g/L Limit	Marketshare of Selected Data That Does Not Meet the 250 g/L Limit	Number of Products that Do Not Meet the 250 g/L Limit, but Meet the 120 g/L (Actual) Limit for Low Solids Coatings	Emission Reduction Lost If These are Now Low-Solids Coatings (excluding South Coast AQMD) (tons/day)
All	35.7%	235	941	100.0%	695	48.5%	56	0.010
2	11.6%	328	177	12.5%	59	2.0%	49	0.007
1.5	10.1%	318	123	10.5%	45	2.0%	35	0.006

Table 5

Low Solids Weight Limit Evaluation - Waterproofing Sealers
(64.8% of Data by Volume - See Note)

Solids Weight Limit (lbs/gallon)	Sales Weighted Average % By Volume Solids	Sales Weighted Average VOC Regulatory (g/L)	Number of Products	Marketshare of Selected Data	Number of Products That Do Not Meet the 250 g/L Limit	Marketshare of Selected Data That Does Not Meet the 250 g/L Limit	Number of Products that Do Not Meet the 250 g/L Limit, but Meet the 120 g/L (Actual) Limit for Low Solids Coatings	Emission Reduction Lost If These are Now Low-Solids Coatings (excluding South Coast AQMD) (tons/day)
All	49.1%	323	71	100.0%	44	86.8%	13	0.006
2	9.7%	305	35	14.1%	9	3.0%	9	0.002
1.5	9.5%	301	31	13.9%	8	3.0%	8	0.002
1	9.3%	291	26	13.3%	8	3.0%	8	0.002

Note: Some of the products reported in the 1998 Architectural Coatings Survey did not include data in a form that was needed to generate the information in the above tables. Therefore, the values in these tables are based on a partial selection of data from the given category, and they may differ from values reported in the Staff Report, which were based on all reported data in a category.

is not a consistent relationship between volume solids levels and coverage. Therefore, as discussed in Issue #1 above, further research is necessary to investigate the relationship between coating volume solids content and coverage.

4) Issue: For some coatings such as waterproofing sealers, coverage is not related to volume solids levels.

Response: As discussed above in Issues #1, #2, and #3, we believe that further investigation of the relationship between volume solids levels and coverage is necessary.

5) Issue: Coverage is not necessarily related to volume solids levels because higher volume solids coatings may just go on thicker. There is no minimum requirement for coverage in rules' tables of standards, and different types of solids vary in their hiding power.

Response: We agree that for a given product or product comparison, coverage may not be directly related to solids. We recognize that there are many factors beyond simply solids levels that affect coverage, such as the hiding power of the various pigments used (which vary with each color), the structure of the film, the method of application, etc. However, since all the various factors that contribute to coverage cannot be incorporated into a VOC equation, we believe the key issue is determining the best indicator of ultimate emissions. For example, the VOC actual and percent by weight VOC do not account for volume solids levels at all, while the VOC regulatory and weight VOC/volume solids calculations are based on the assumption that there is a definite relationship between volume solids and coverage. We believe further investigation of the relationship between volume solids and coverage is necessary to determine which of these (or another equation) is the best indicator of ultimate emissions in use.

6) Issue: Method 24 has poor precision in determining VOC regulatory for low-VOC water-based coatings.

Response: We agree. Studies have demonstrated poor precision when determining the VOC regulatory for low-VOC water-based coatings compared to that for solvent-based coatings (Brezinski, p. 19-20; South Coast AQMD Memo). The poor precision obtained with the water-reducible coatings with high water content and low VOC levels is attributed to the mathematical expression used to calculate VOC regulatory. Since water content is subtracted from the volume in the denominator, any error shown in the numerator of the equation is magnified when divided by an increasingly small number. This

magnification of error in coatings with high water content was not found when testing VOC actual (Brezinski, p. 19).

7) Issue: A true comparison of coatings in terms of the emissions would look at ozone formed, coverage, and product lifetime.

Response: We agree. However, the VOC regulatory equation is the best indicator of emissions at this time, because it measures the VOC emissions of both water-based and solvent-based products on an equal (volume solids-related) basis, if one assumes that volume solids content of paint is directly related to coverage. We are currently investigating the feasibility of developing standards based on the reactivity of individual VOCs which will more accurately reflect ozone formed. Regarding coverage and product lifetime, it is difficult to estimate these quantities due to all the factors that affect each (please see the response to comment #5 regarding factors affecting coverage).

8) Issue: VOC regulatory should be the ratio of the weight VOC to volume solids (not the combined volume of solids and VOC).

Response: We agree, except that there are concerns with the available test methods used to measure this quantity, as discussed in Section V.

9) Issue: VOC regulatory is only useful in the table of standards, and cannot directly be used to calculate emissions.

Response: It is true that the VOC regulatory cannot directly be used to calculate emissions. It is also somewhat confusing to understand. However, the key issue is whether it is the best indicator of the VOC emissions from a variety of products (water-based and solvent-based), and whether it allows valid and useful comparisons between products.

10) Issue: VOC actual is the actual VOC content in the can and would be more useful to architects, contractors, consumers, etc. looking for low-VOC products. VOC regulatory represents the actual VOC content in the can only for coatings with no water or exempt compounds, and may reduce the incentive to use water-based coatings.

Response: This statement is only true if VOC actual is a better indicator of VOC emissions than VOC regulatory, which depends on whether volume solids levels are related to coverage. As discussed in Issues #1 and #3 above, more research is needed in this area.

11) Issue: Architectural coatings are being treated unfairly because the ARB consumer products regulation uses weight percent VOC limits.

Response: We disagree. Whether the VOC limits are based on grams of VOC per liter of coating, or weight percent, or any other value, they would be set at the same relative stringency based on available lower VOC technology, cost-effectiveness, emission reductions, and other factors. It is logical that architectural coatings are based on VOC regulatory because they are coating products and it is not unreasonable to use an equation that accounts for volume solids as an indicator of coverage (although this is subject to debate as discussed in Issues #1 and #3 above). Consumer products, in contrast, are an extremely diverse group of products. For many consumer products, such as cleaning products, usage rates clearly have no relationship to volume solids or coverage.

12) Issue: Water is an integral part of water-based formulations (for example, increasing coating transparency with faux and glazing compounds) and should not be subtracted out of the VOC calculation. The VOC for faux/glazing compounds should be calculated on a weight VOC to volume coating basis (not less water).

Response: We agree that water is an integral part of water-based formulations, including faux/glazing compounds. However, as discussed in Issues #1 and #3 above, whether water-based products are penalized by the VOC regulatory calculation depends on whether coverage is related to volume solids levels. Coatings with large water contents, such as faux/glazing compounds, should be investigated in any potential future research into the relationship between volume solids and coverage, or in investigating an alternative definition of low volume solids coatings, such as the ratio of VOC regulatory/VOC actual.

V. Alternative VOC Equations

1. VOC actual:

This is the ratio of the weight of VOC to the volume of the entire coating, including water and any exempt compounds. As such, it gives the actual VOC in a can of paint if the units are given in pounds VOC per gallon and the paint is provided in gallon cans (or the VOC in the container can be easily calculated). This has the advantage of being easier to understand than VOC regulatory. The VOC actual value is currently used to calculate emissions, and it is used to measure the VOC content of low volume solids coatings (which are not amenable to the VOC regulatory calculation (see Issue #2 above)). In addition, precision is better when coatings with a high water content are analyzed for VOC content using this equation (see issue # 6 above.) The disadvantage of this equation is that the VOC content is not calculated on a volume solids basis, but rather on a product basis. Depending on the validity of the assumption that volume solids dictate coverage, two products with the same VOC actual could have very different volume solids levels and thus coverage, leading ultimately to

higher VOC emissions to cover a given surface with the lower volume solids formulation. Again, ARB staff analysis did not find such a relationship, based on a review of product data sheets.

2. Weight percent VOC:

This is similar to the VOC actual equation above, except that it is the ratio of the weight of the VOC to the *weight* of the coating. As with the VOC actual equation, it has the advantage of being easier to understand than VOC regulatory, and can be used to analyze coatings with a high water content more precisely than with the VOC regulatory. It is currently used in ARB consumer products regulations for a variety of different types of products, including aerosol paints. The disadvantage of using weight percent is that it does not account for coating volume solids. Like the VOC actual calculation, depending on the validity of the assumption that volume solids dictates coverage, one could have two products with the same weight percent VOC, but very different volume solids levels and coverage, leading ultimately to higher VOC emissions to cover a given surface with the lower volume solids formulation. However, ARB staff did not find such a relationship, based on product data sheets.

3. Weight VOC/volume solids:

This would be the ideal equation to use assuming that volume solids levels dictate coverage. U.S. EPA reportedly originally would have preferred using this equation over the VOC regulatory equation (Brezinski, p.7). However, at the time, there was no recognized acceptable test method for determining the volume of coating solids. There are now VOC emission limits for several new source performance standards that are expressed as the weight of VOC emitted per volume of coating solids. Currently, U.S. EPA only allows the volume of coating solids to be determined using paint formulation data, although proposed Maximum Achievable Control Technology standards for coil coatings and large appliances include the following volume solids test methods.

There is an ASTM method for determining the volume of coating solids, ASTM D-2697, “Test Method for Volume Nonvolatile Matter in Clear or Pigment Coatings.” However, U.S. EPA has not approved ASTM D-2697 at this time. ASTM D-2697 utilizes Archimedes’ principle that a body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid. During part of the test procedure, a disk with the dried coating is immersed in the test fluid. This is reportedly problematic for paints with air spaces in the coating film, such as certain flat wall paints, metal primers containing zinc dust, certain primers, and coatings containing raw materials with internal air pockets. For this reason, and due to the long time required to do the test (about 2 hours), it is only performed by a few labs in the coatings industry (Brezinski, p. 15).

Another method is a procedure that uses the helium pycnometer to measure the density of coating solids (ASTM D-6093). In place of the displacement of liquid as in ASTM D-2697, helium gas is used. The gas permeates through voids in the paint film replacing entrapped air. The total volume of helium displaced by the coating is derived from the change in helium gas pressure (Brezinski, p. 28-29). There are reportedly some concerns with this method for coatings that are designed to contain voids in order to extend coverage (Ameron, 1/26/01).

Due to the difficulty in measuring the volume of solids, manufacturers have suggested measuring the weight of VOC per *weight* of solids (Sherwin Williams, among others). According to these manufacturers, using the weight instead of volume would be equally valid since both weight and volume are relatively inaccurate measures of coverage, and the weight of solids can be more precisely determined in the laboratory. However, U.S. EPA may view the volume solids as a better indicator of coverage because it also applies to other coating applications where a mil thickness multiplied by a surface area results in the volume of solids needed to coat a given surface.

4. Reactivity-based standards:

ARB is currently exploring reactivity-based standards for architectural coatings, which differ from traditional mass-based standards in that they are based on the ozone-forming potential of the emissions from the coatings, rather than simply on the mass of emissions from the coatings. An example of such reactivity-based standards is the ARB's aerosol coatings regulation, which the Board amended in June 2000 to include reactivity-based standards. If a reactivity-based approach is developed for architectural coatings, then the less-water and less exempt compounds VOC calculation becomes moot. However, the focus of this analysis is on the VOC calculation, so we will not discuss reactivity-based standards further here. It is brought up simply as a point of information and to indicate possible future directions.

VI. Implications of Changing the VOC Equation

Changing the VOC calculation would result in some significant consequences, including the following:

1) The VOC limits would need to be modified to ensure that the VOC reductions achieved using the VOC regulatory equation were still being achieved using a new standard;

2) U.S. EPA may not approve rules using the new VOC limits as part of the State Implementation Plan;

3) Depending on the new VOC equation used, it may favor one technology over another. For example, using VOC actual may adversely impact solvent-based coatings. If VOC actual were used, most solventborne coatings would have the same VOC contents, but waterborne coatings would have a lower VOC than before. If a VOC actual limit were adopted, the numerical value of the limit would decrease, and some solventborne coatings that would have previously complied, may not comply under the new standard. Alternatively, using VOC actual may allow coatings that had a low volume solids content and a high water content to comply, when they did not do so before.

4) The VOC limits would be inconsistent with other district rules, making it confusing in cases where a paint can be used in dual applications covering both architectural and other coatings applications; and

5) Relabeling would be required with the new VOC limit, or dual labeling with both VOC limits to reflect district rules and the National Architectural Coatings Rule.

VII. ARB Technical Analysis

1. Comparison of VOC Measures:

ARB generated equivalent alternative VOC limits (VOC actual, percent VOC by weight, and grams VOC per liter of solids) for the ten largest architectural coatings categories (as shown in Table 1). The alternative VOC limits were set such that they achieve the same emission reductions as the VOC regulatory limits in the SCM. The VOC limits vary widely numerically from the VOC regulatory values. However, as they are designed to achieve equivalent emission reductions, they are overall similar in stringency, and should require similar overall reformulation efforts. In other words, if the limits are much lower numerically, the existing products on the market would be expected to be similarly lower numerically compared to their current VOC regulatory values. Nevertheless, some individual products or product types could be impacted more than others under the alternative VOC measures. For example, solvent-based products would be impacted much more than water-based products under VOC actual limits. This is because VOC actual limits are numerically lower than VOC regulatory limits. Solvent-based coatings that contain no water or exempt VOCs have a VOC actual value that is equal to the VOC regulatory value. If VOC actual limits were in place, the solvent-based coatings would have to meet a lower limit even if they might have otherwise complied with VOC regulatory limits. The water-based coatings typically have a VOC actual value that is much lower than their VOC regulatory value, and could use this value to meet the alternate limit.

2. Percent volume solids versus VOC regulatory limit:

ARB graphed percent solids (by volume) versus the VOC regulatory for each of the major architectural coatings categories recently surveyed during the development of the SCM for both solvent-based coatings and water-based coatings. Graphs were also developed for percent volume solids versus VOC actual for the water-based coatings. These graphs are arranged by coating category (See Figures A-1 through A-28 in the Appendix). In addition, graphs were developed for all solvent-based products combined, and all water-based products combined, showing the changes in percent by volume water, solids, and VOC, as VOC regulatory changes (See Figures 5 and 6).

Based on the results of the graphs, the trend among the solvent–based product categories is that VOC regulatory is inversely related to the percent volume solids. This is almost a mathematical certainty since solvent-based products generally contain only solids and VOC solvent (except those few with exempt compounds). The only way to reduce the VOC for these products is to increase the volume solids content.

With water-based products, by comparison, there is not a consistent relationship. In other words, the volume of solids is not inversely proportional to the amount of VOC in the coating. For many water-based coatings categories, the percent solids by volume is relatively constant with changes in the VOC regulatory. For most other water-based categories, there is an inverse relationship between VOC regulatory and percent solids. Overall for water-based products, there is a gradual decline in percent volume solids as the VOC regulatory increases. For the categories with relatively constant volume solids levels (flats, low and medium gloss nonflats, etc.) this means that the differences in VOC regulatory are accounted for by the relative amounts of VOCs and water in these products. In other words, the lower VOC products have relatively less VOCs and more water, while keeping the percentage of volume solids relatively constant.

These graphs also illustrate that for the same VOC regulatory content, water-based coatings generally have less volume solids than solvent-based coatings. The graphs of the volume solids amount versus VOC actual for the water-based coatings also illustrate this point, and are included for comparison purposes.

Figure 5

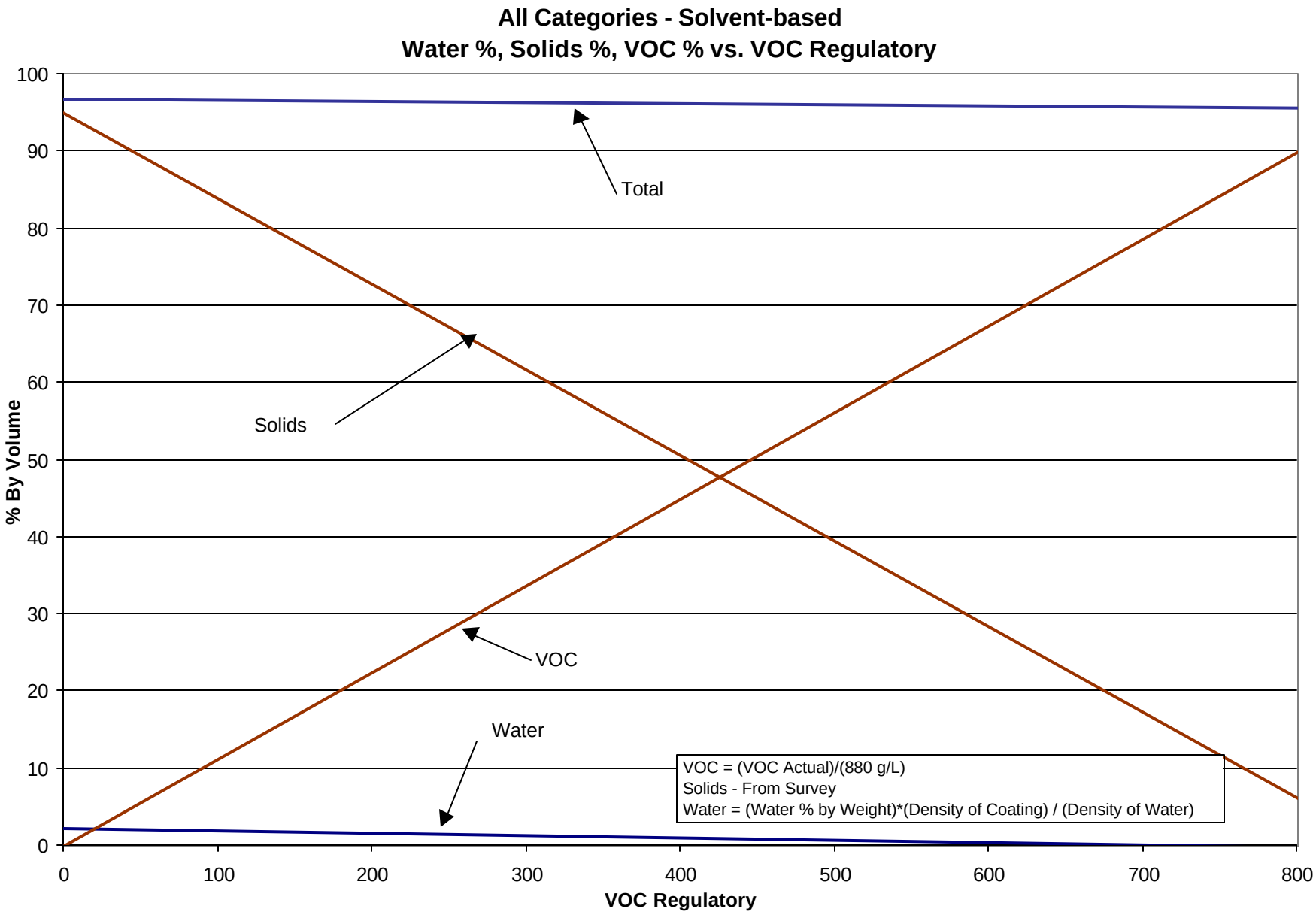
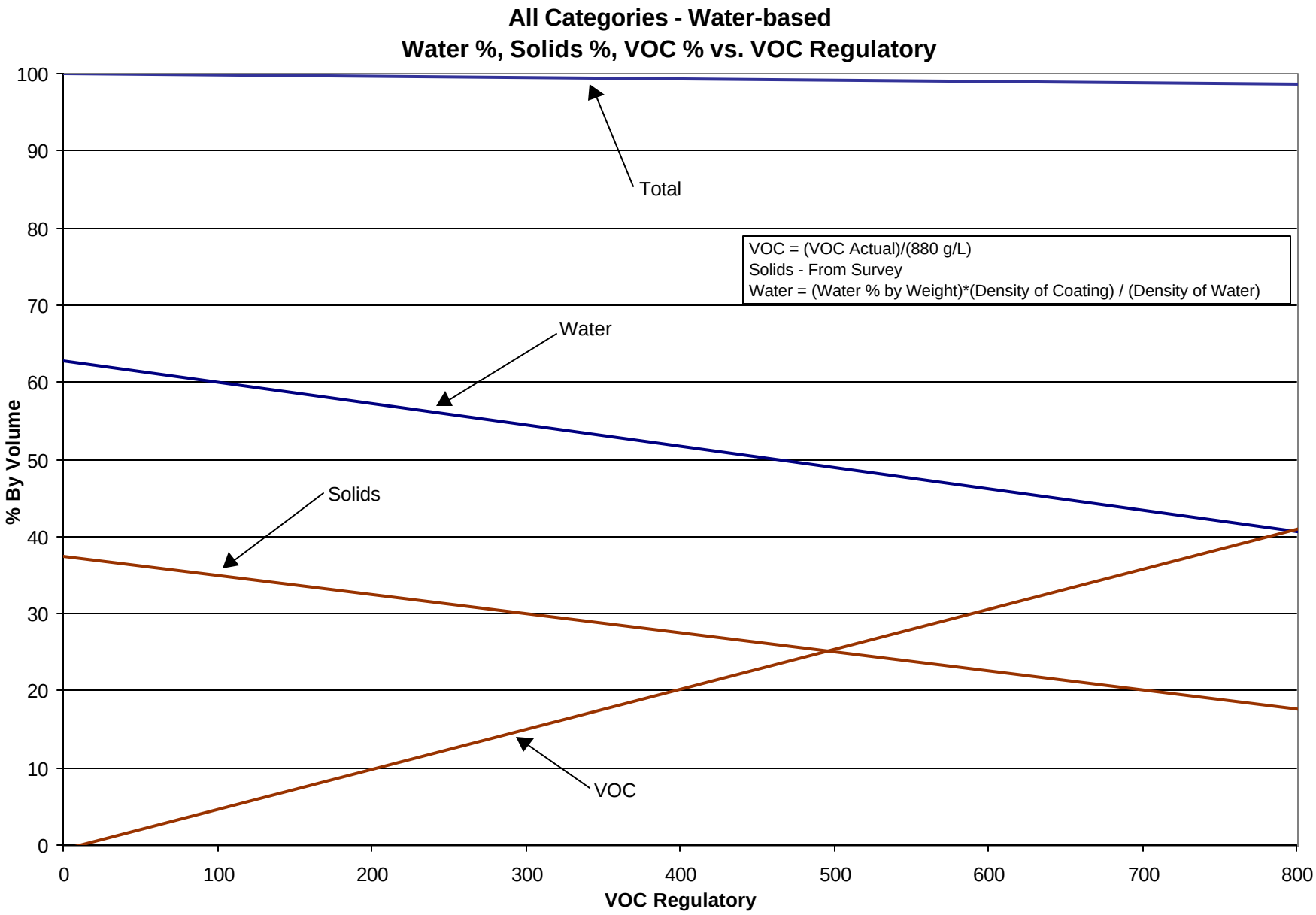

All Categories - Solvent-based
Water %, Solids %, VOC % vs. VOC Regulatory
% By Volume
VOC Regulatory
Total
Solids
VOC
Water
VOC = (VOC Actual)/(880 g/L)
Solids - From Survey
Water = (Water % by Weight)*(Density of Coating) / (Density of Water)
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800

Figure 6


All Categories - Water-based
Water %, Solids %, VOC % vs. VOC Regulatory
100
90
80
70
60
50
40
30
20
10
0
% By Volume
0
100
200
300
400
500
600
700
800
VOC Regulatory
Total
Water
Solids
VOC
VOC = (VOC Actual)/(880 g/L)
Solids - From Survey
Water = (Water % by Weight)*(Density of Coating) / (Density of Water)

3. VOC regulatory/VOC actual ratio for low volume solids coatings:

ARB staff prepared tables showing the impact of applying a VOC regulatory/VOC actual ratio to the stains and waterproofing sealers, which is discussed in Issue #2 above (See Tables 2 and 3). In addition, we prepared similar tables showing the impact of different solids content definitions for low-solids coatings, which is also discussed in Issue #2 above (See Tables 4 and 5).

VIII. Next Steps

- Further investigation of the link between coating volume solids and coverage/hiding is necessary to determine which VOC measure is most appropriate. This is particularly true for waterproofing sealers and faux/glazing coatings. If there is a definite link between coatings solids (by weight or volume), and coverage/hiding, then the VOC regulatory or weight VOC/volume solids limit would be appropriate. On the other hand, if there is no clear relationship between solids levels and coverage, then the VOC actual or weight percent VOC may be more appropriate. To perform the research, a research contractor with experience testing paints and coatings could be hired. We envision that the contractor would design and implement a study to evaluate the coverage of coatings while varying the level of coating solids and the type of solids. The contractor could formulate paints while varying the type and amount of solids, or utilize a range of existing products in the marketplace, and perform application tests to measure coverage. ASTM tests should be utilized wherever available. Ideally, if coverage is not found to be related to the amount of volume solids, then the contractor should attempt to determine the key factors that result in better coverage/hiding.

- In addition, further investigation should be conducted regarding the appropriateness of the one pound of solids definition of a low solids coating. This may need to wait until after the next ARB architectural coatings survey, which would collect the necessary data.

- If a different VOC measure is determined to be more appropriate, it would be necessary to address each of the factors discussed in Section VI above. It would be less burdensome to industry to implement any changes in the VOC limits at the same time more stringent future limits are scheduled (even if reactivity-based VOC limits are to be implemented, many of the same issues in Section VI apply as for mass-based VOC limits). Otherwise, industry would need to reformulate a significant percentage of their products simply to conform to revised VOC limits that achieve equivalent emission reductions.

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